2nd Workshop on International Cooperation in Spaceborne Imaging Spectroscopy

Towards agriculturally relevant product retrieval from spaceborne spectroscopy data - Status and Challenges

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Session: 3.1.1 - Vegetation Traits Retrieval and Applications - Part 2
Place: La Collinetta Eventi, Rome (Italy), Room "AIRONE"
Time: 08:30-08:38 UTC+2

EnMAP

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

Introduction

EnMAP PRISMA DESIS EMIT CHIME etc…

The new surge of spaceborne spectrometers leads to hyperspectral acquisitions being…

- available (we can get some data)
- projectable (we can schedule parallel in-situ sampling)
- multitemporal (we can observe time-series)

This finally opens the ground for using hyperspectral data in practical agriculture.

What kind of data would farmers use?

Data that helps with deciding about:

- seeding
- fertilization
- plant protection
- irrigation
- harvesting
- long-term melioration effects

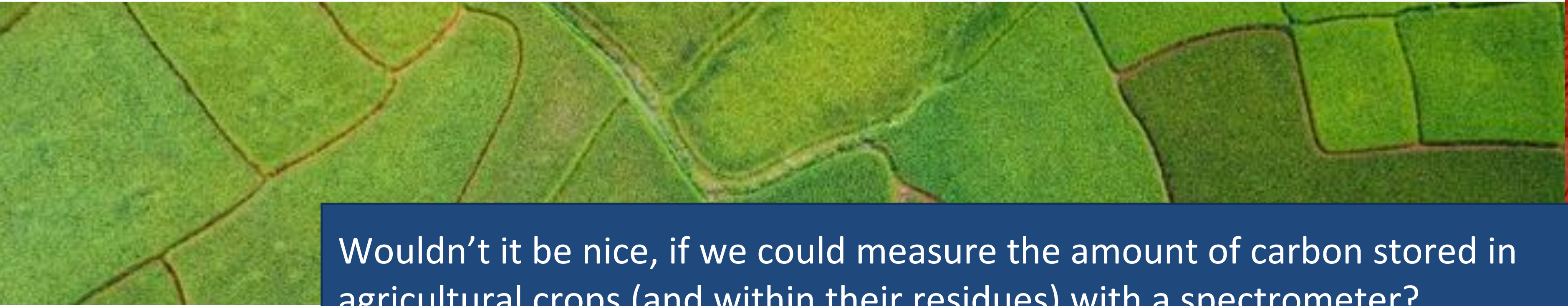
What these practical farming problems all have in common, is that they are about quantities and concrete numbers.

The questions mostly boil down to:

- **How much?**
- **When?**
- ***Which?***

Long-Term Melioration Effects
Long-term melioration effects

- Agriculture (together with forestry and land use change) is contributing approx. 20% of the global GHG emissions.
- Long-Term storage of carbon in agriculturally used soils may play a role as carbon sink (see talk #177 by Heike Bach).
- “Carbon Farming” is part of the EU Green Deal.



Wouldn’t it be nice, if we could measure the amount of carbon stored in agricultural crops (and within their residues) with a spectrometer?

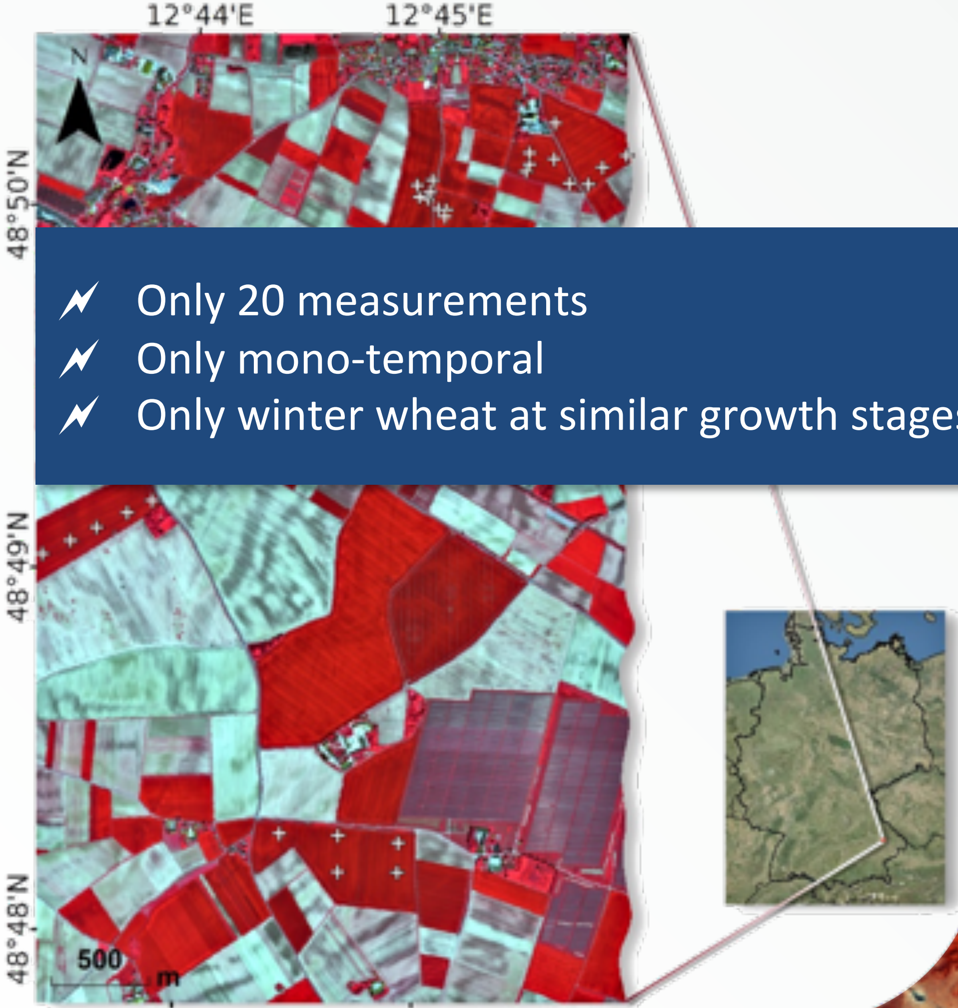
Test Site Irlbach: Location

Europe → Southern Germany → Bavaria → Near Straubing → Center Coordinates: 48.81° N | 12.73° E

Irlbach site | May 30th 2021

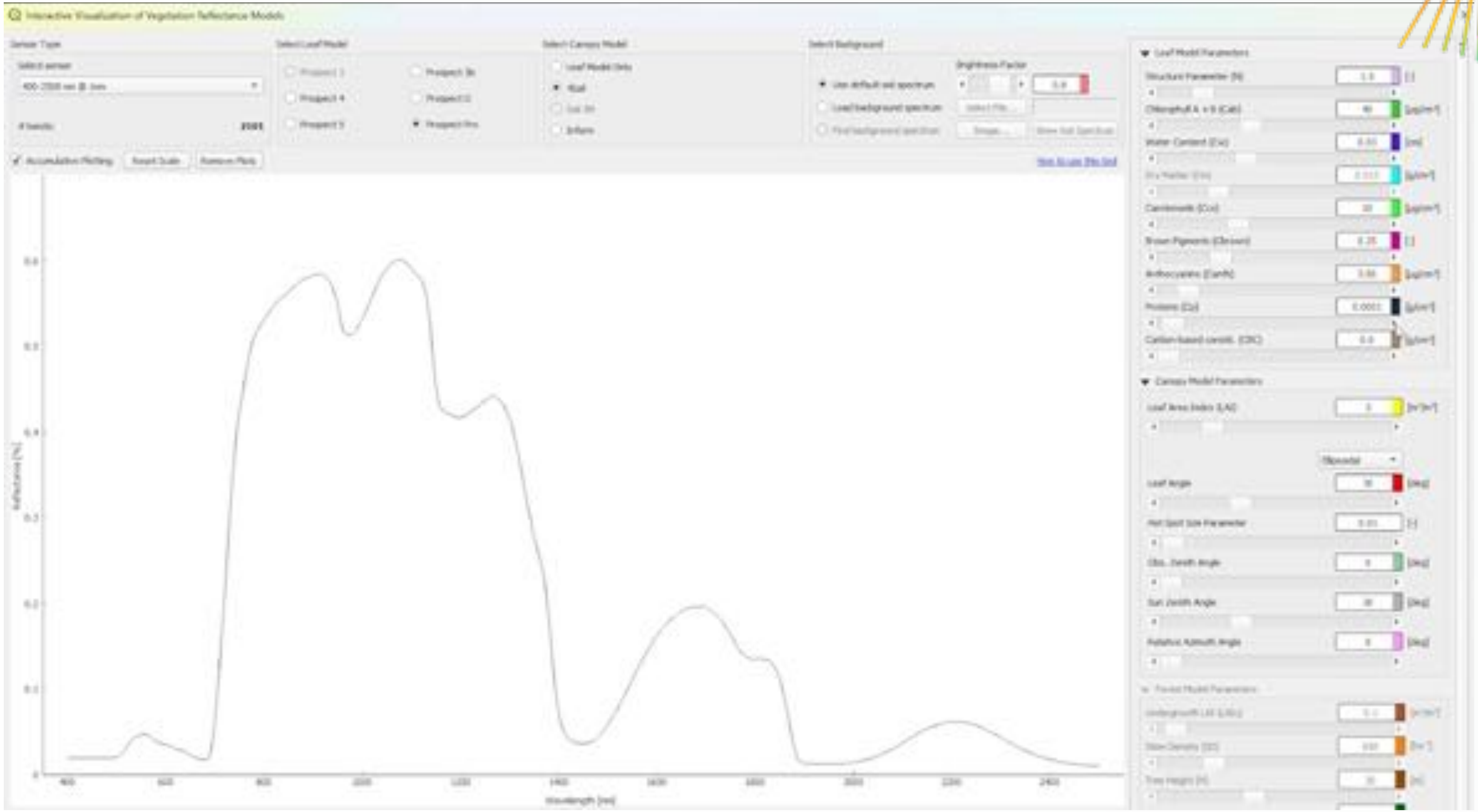
Airborne data:
HyperSense CHIME preparation campaign
AVIRIS-NG airborne acquisitions
(377-2501 nm @425 bands)
→ resampled to EnMAP (233 bands)

In situ data:
- Dry & fresh biomass (AGB_{dry}, AGB_{fresh})
- Carbon content (C_{area})
- Nitrogen content (N_{area})
- Leaf area index (LAI)



- Only 20 measurements
- Only mono-temporal
- Only winter wheat at similar growth stages

Spectral Signal of Carbon-Based Constituents

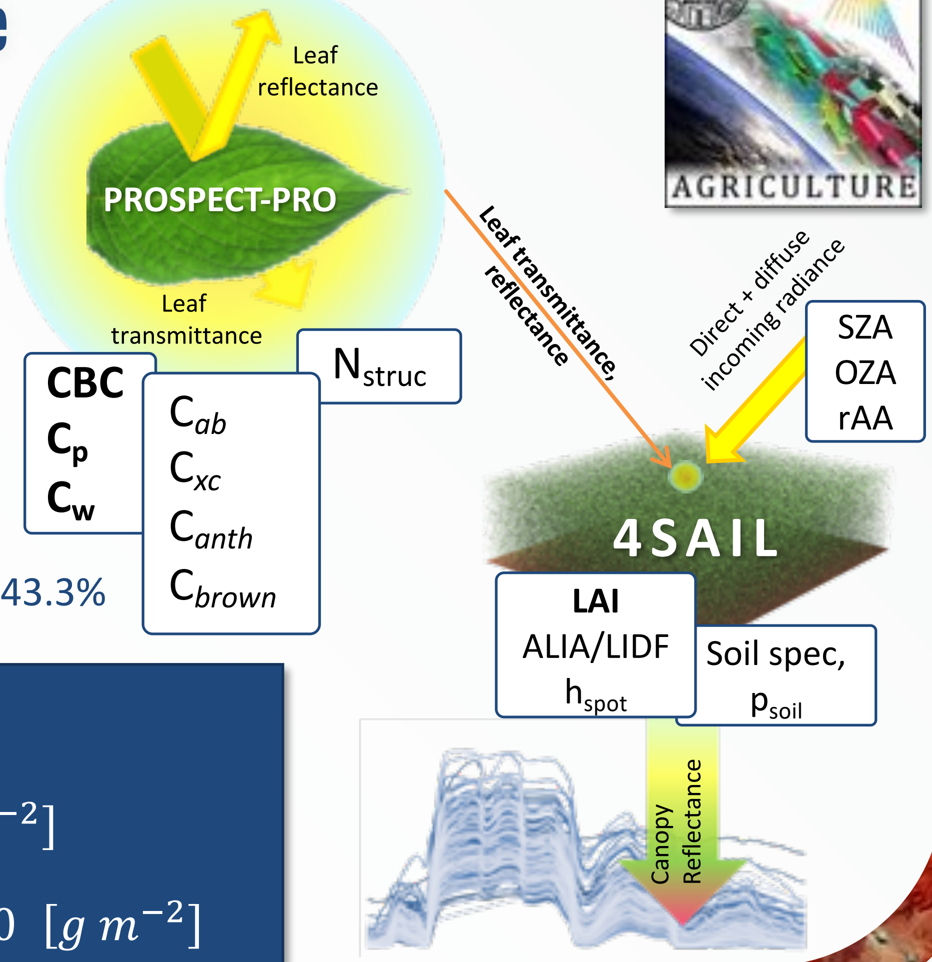


PROSAIL-PRO training database

- 3000 members
- Parameters varied over wide value range

Carbon based constituents (CBC) include sugars, starch, lignin, cellulose and hemicellulose → **CBC ≠ C**

Conversion factor needed!
→ Mean C-concentration (leaves|stalks|fruits) = 43.3%

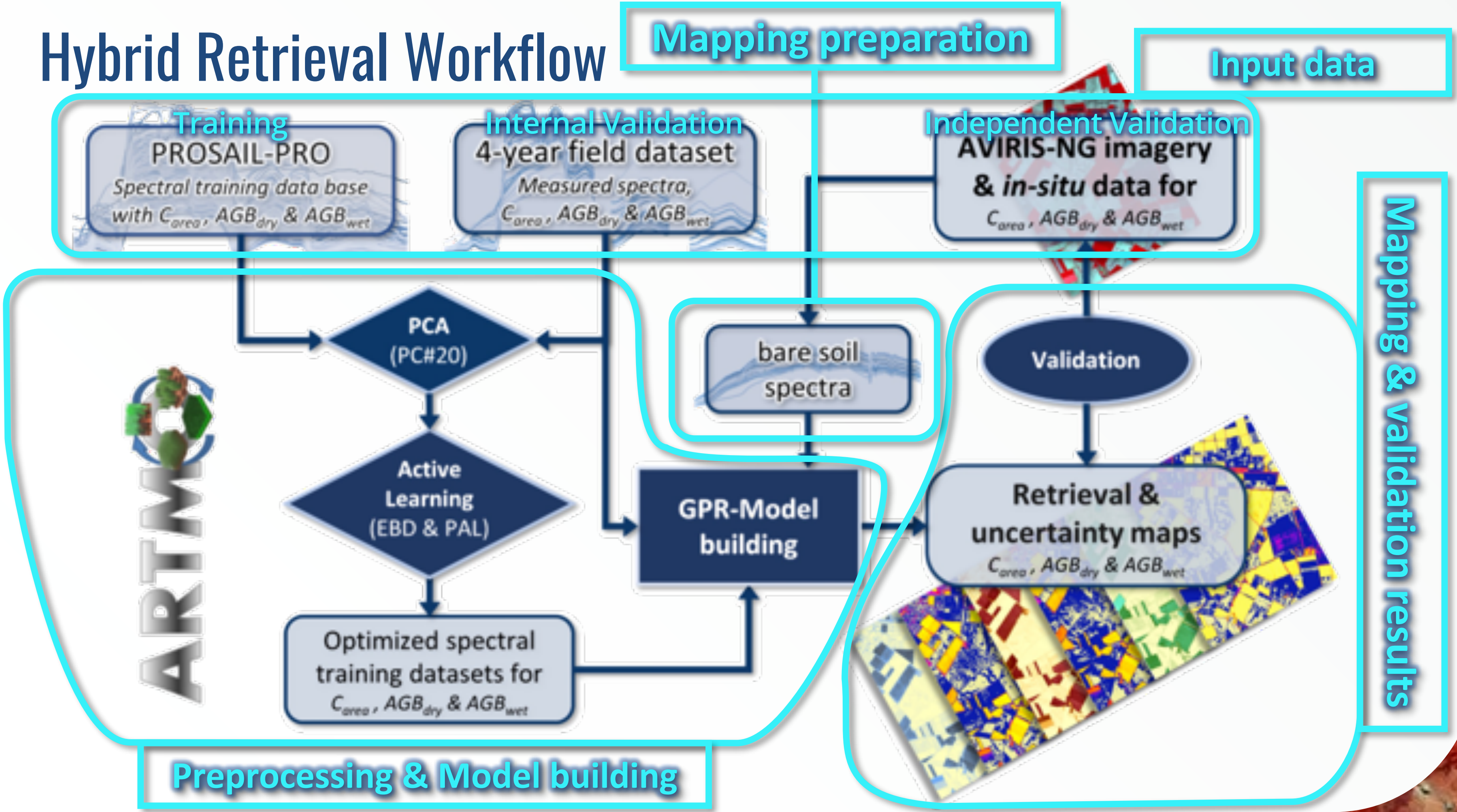


$$C_{area} = \frac{CBC \times LAI \times 10{,}000}{2.31} \; [g\ m^{-2}]$$

$$AGB_{dry} = (C_p + CBC) \times LAI \times 10{,}000 \; [g\ m^{-2}]$$

$$AGB_{fresh} = (C_p + CBC + C_w) \times LAI \times 10{,}000 \; [g\ m^{-2}]$$

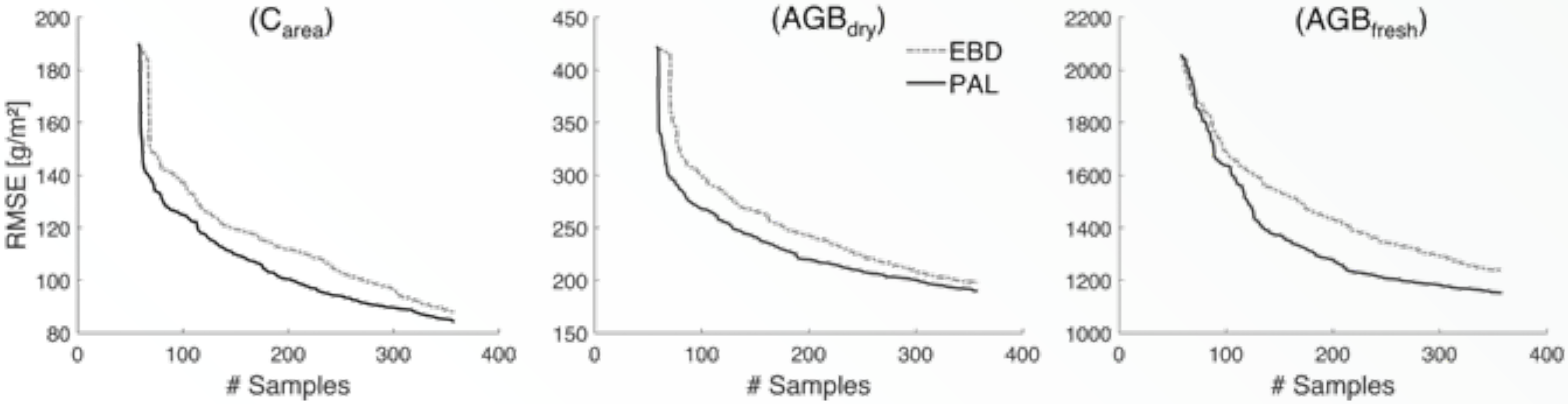
Hybrid Retrieval Workflow



Dimensionality reduction and Active Learning

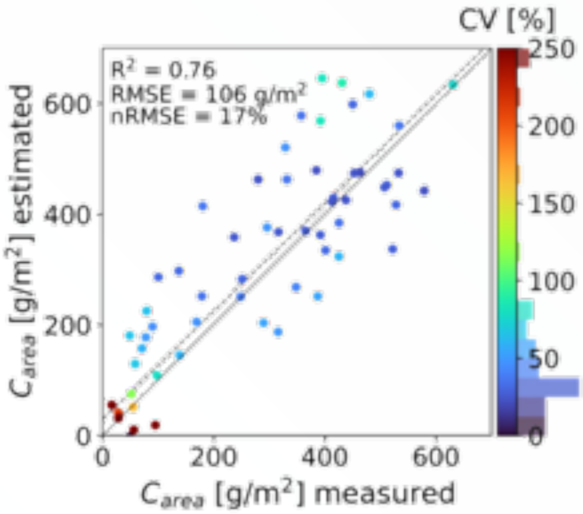
- Application of Principal Component Analysis (PCA) with 20 components (addressing collinearity, maximizing algorithmic interpretability, minimizing information loss)
- Sampling optimization using two Active Learning (AL) approaches
  - Euclidian distance based (EDB)
  - Pool active learning (PAL)

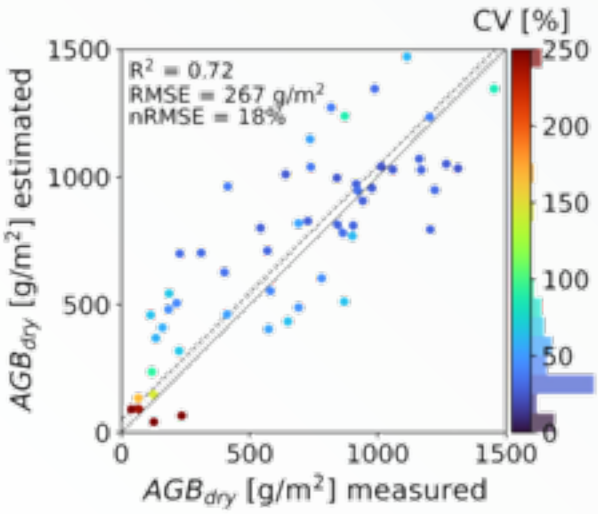
https://artmotoolbox.com/

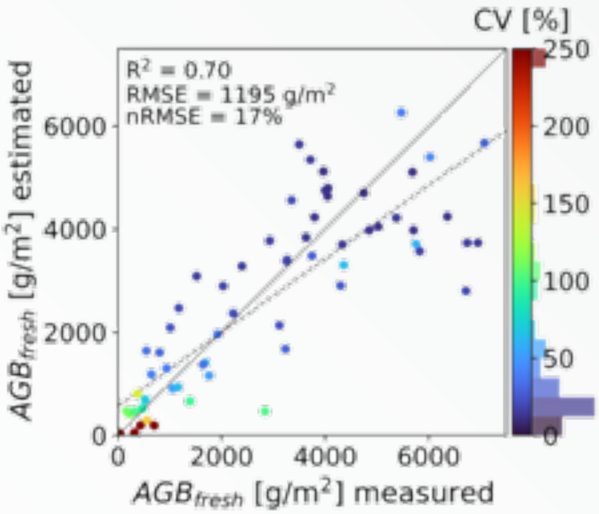


- Reduction of training database by **88%** from 3000 to 358 members

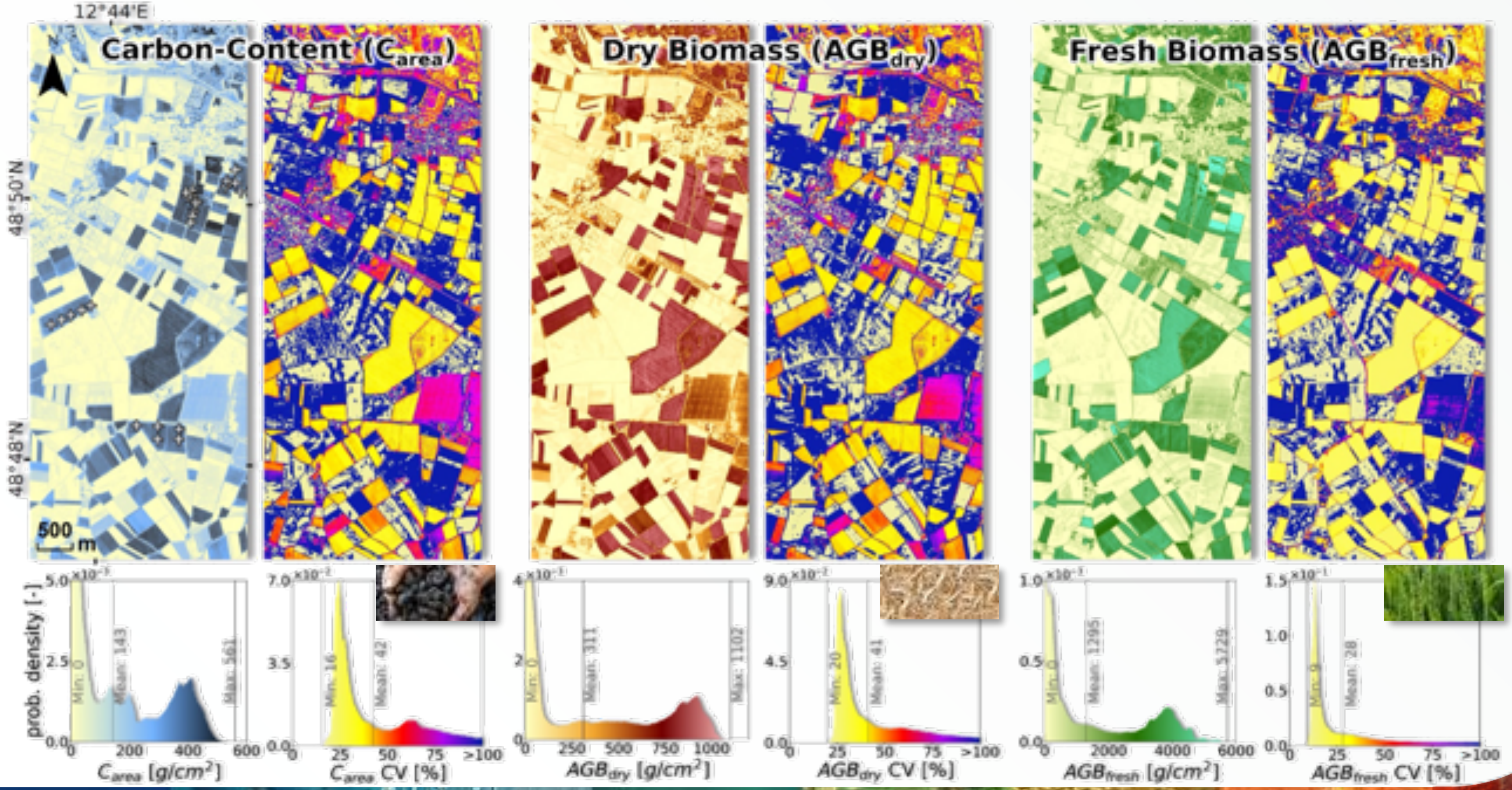
Internal Validation of the GPR Model



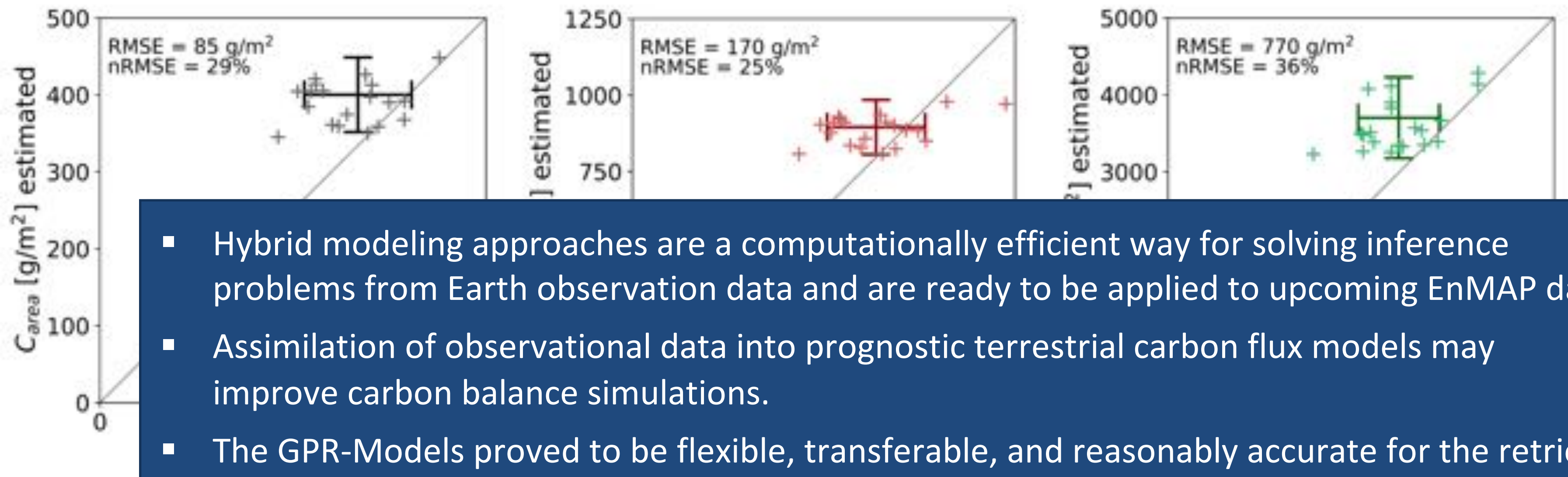




Spatial Mapping with the GPR Model



Independent Validation of the GPR Model Results



- Hybrid modeling approaches are a computationally efficient way for solving inference problems from Earth observation data and are ready to be applied to upcoming EnMAP data.
- Assimilation of observational data into prognostic terrestrial carbon flux models may improve carbon balance simulations.
- The GPR-Models proved to be flexible, transferable, and reasonably accurate for the retrieval of C_{area}, AGB_{dry}, and AGB_{fresh} from (simulated) EnMAP data.

Conclusions

- The questions of practical agriculture are of a **quantitative** nature.
  → We need to concentrate on those variables that come **with physical units**.

- Crop development is a **temporally highly dynamic** process.
  → We need to learn to make the best possible use of **time-series** from imaging spectrometers.

- Models are **digital twins** of the real world.
  → We need to bring **everything that needs mapping** into the digital world.

- There still are strong **deviations** between modeled and measured reflectances.
  → We need to get back into the lab and into the field and **improve the models**.

- At the same time don‘t let us forget **all the data** that we have collected during the last 40 years.
  → We need to share and harmonize this data to improve **transferability** of statistical models.

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Thank You for Your Attention!

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www.geographie.uni-muenchen.de

www.enmap.org

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